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Walrus architecture

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INTRODUCTION

"Thermal adaptation comprises the physiological and morphological changes which reduce the strains of stressful environments" (1). "Natural selection acts on the capacity for change within a given genotype; hence it is important to learn how such an environmental variable as temperature brings about change" (2). How does an environmental variable such as temperature bring about change in architecture?

The remarkable thermal adaptation of the walrus's membrane is an innovative example of nature's ingenuity. A walrus and camel have the same general resting metabolic rate under typical thermal conditions for the environment they are adapted for (3). Is this true of typical modern architecture? How would the normal metabolic rate (energy consumption) of a building in Anchorage Alaska compare to a building in Phoenix Arizona? What if energy consumption for all buildings were to remain the same no matter what the thermal conditions. This is just how the walrus and camel have evolved (2). Architecture should pay close attention to this adaptive design path.

Architecture has reached another point in its history where innovation and technology are now capable of leading it down a new evolutionary branch. However, while structural discoveries such as the flying buttresses of the Gothic era and steel framing of the Industrial era defined architectural innovations of the past, material technologies from high carbon fiber composites to high performance polyurethane foam insulations are defining architectural innovation today. The thermal performances of these innovations may have a profound impact on the energy design of architecture by replacing its typical massive furnaces and air conditioners as the primary system for thermal control. However the question for architects is more than just how these innovations should be incorporated functionally, but also how this function can inform aesthetic expression. These new technologies should be more than just stuffed between bricks and sheetrock.

The thermal characteristics of these new technologies closely resemble animal thermal adaptations. Since architecture and walruses are both faced with the same internal problem of thermal stability it seems only logical to look to animal adaptations to understand how these new innovations could be implemented into architectural design. With an emphasis on design expression of these thermal materials, this project is split between both investigation and exploration of thermal adaptations. The first, being an evolutionary investigation of animal and architecture thermal strategies. The second is the exploration of thermal expression in architectural design.

THE SIGNIFICANCE OF A WALRUS ARCHITECTURE

From glamour wrapped glass skyscrapers to simple metal clad mobile homes all architectural design could benefit by using these new technologies incorporated through new design methods. The walrus's membrane performs the primary role in thermal performance. If architecture would follow the same thermal strategy this would greatly decrease architecture's dependence on energy consumption and also better prepare itself for the inevitable.

It appears that architectural design is currently influenced more by economic, aesthetic, and cheap energy considerations than by future inevitabilities. These three factors are important because for the most part architecture is a consumer product to be sold. However, it is not just like a pair of jeans sold at the local clothing store. The consumer buys a pair of jeans which are of the latest fad then three years later are thrown away once they are worn out. Jeans are a short-term product. Unlike the majority of consumer products, such as the jeans, Architecture is unique because it is a long-term product. A product which is not only to be used by more than one consumer, but also is to be passed on to consumers of future generations. Architectural design should be focused on not only providing a quality product to the consumers of today, but also attempting to provide a quality product to the consumers of tomorrow.

The inevitable dry-up of our nonrenewable energy resources will affect society in the future on many levels. One of the most significant is directly related to the architectural design of today, which implements the heating and cooling mechanical system as the primary system for thermal control. Because of this, the energy dry-up will leave consumers stranded in homes thermally designed to be dependent on energy consumption, energy such as natural gas. Once this gas is gone so to is the homeowner's heat.

Because of architecture's massive size, even for the smallest of homes, it is not an easy retrofit. The size of a home or any building for the most part directly correlates to the consumer's financial limitations. If the consumers of the future are similar to the consumers of today, they will be burdened with the financial strain of retrofitting a home's mechanical system. So, if today's typical architectural design continues to be applied, a greater and greater strain is thrown upon the consumers of the future. There are thermal designs which use strategies that will not "dry up". Strategies which for the most part can be guaranteed, such as the sun and an efficient thermal membrane.

Another reason for a new thermal design path is using our resources more efficiently. Increased thermal efficiency reduces energy consumption thus allowing these high-performance nonrenewable resources to be used more efficiently in factories. For example natural gas used in a typical home for general heating purposes is burned at an average temperature far below its maximum potential, while it is used to its full potential in industrial practices, where levels of high heat production are required. Once burned this resource is gone forever. Given the fact that architecture today consumes half of the world's energy, the potential energy loss is staggering. Think about the thousands of gallons of natural gas being pumped into all the homes across just the United States.

The goal of architectural design should be to prepare for the future by not being completely defined by present day criteria. It's about designing to be less vulnerable to the inevitable. By reevaluating membrane design architects could reduce energy consumption and dependence on nonrenewable energy resources. The result could be an architecture that not only begins to solve today's architectural problems, but could also begin to prepare itself for the problems of the future.

THERMAL ENVIRONMENT

Energy occurs in either of two forms (4). The first is potential energy. This is inactive and stored away. The other form is kinetic energy and is what defines the thermal environment. Energy is never created nor destroyed, but only cycles through the universe by transforming continually back and forth between these two forms.

Potential energy is found on the tip of a match when lighting a campfire, swashing around in a gas tank while driving down the road, and stuffed into a bagel that is eaten at breakfast. It is also the giant masses of hydrogen that dot our universe and galaxies known as stars and more personally the sun of our own solar system. Through a variety of chemical reactions on the tip of the match to the fission reactions in the sun this potential energy is then ignited and released as kinetic energy into the thermal environment. This kinetic energy then circulates through the thermal environment until being absorbed in a variety of ways such as through photosynthesis in the cells of plant leaves, where it is converted back into potential energy within the fibers of the plant.

The thermal environment is measured by temperature and defined by kinetic energy. It is more than just hot and cold, which are only descriptions of how we explain the sensations we encounter, as our own bodies react and interpret variances in the thermal environment. These descriptions are misleading because on a warm day in summer an air-conditioned building that is 70 degrees Fahrenheit feels cool, while on a cool day in winter the same 70 degree air feels warm. A clear understanding of the thermal environment is found in the laws of kinetic energy as it transfers energy (heat) by two processes, vibrations and electromagnetic wavelengths.(5) The vibrations, termed conduction, are what truly define the thermal environment. While electromagnetic wavelengths, termed radiation, and a third by-product process, termed convection, only influence the vibrations of the thermal environment.

Conduction - Vibrating Atoms

Energy causes atoms to vibrate which then creates temperature. The faster the atoms vibrate the higher the temperature. The greater the amount of energy being released the greater the vibrations and so the higher the temperature. However, these vibrations do not remain constant within each atom because of their tendency to transfer energy. Conduction is the term, which describes the process of energy transfer by vibrations.

> "Conduction is the transfer of energy through a material medium by the successive collisions of neighboring molecules" (6).

As each atom vibrates it collides with other atoms. Through this sequence of collisions faster vibrating atoms collide with slower vibrating atoms and through the collision energy from the faster vibrating atom is passed on to the slower atom causing it to vibrate faster, while with the loss of energy the faster vibrating atom slows. This process of collisions continues until both atoms are vibrating at the same rate.

> "In this way energy is transferred from the higher to the lower-temperature part of the medium while the molecules remain near their original positions" (7).

This equalization rarely occurs however and if it does is only temporary due to the fact that new kinetic energy is constantly ignited into the thermal environment.

To understand the complexity of the thermal environment's state of constant flux imagine the universe as a pond on a calm day. The water lays flat like a mirror. A handful of rocks are thrown out into the pond. These rocks represent potential energy and the surface of the pond represents the thermal environment. Imagine each rock breaking the pond's surface at the same time. At this moment imagine a chemical reaction is occurring igniting the potential energy (the rock) into kinetic energy, which is represented by the ripples. From each point of ignition the kinetic energy radiates out from their point of origin. These ripples represent a single wave of vibrations rippling through the thermal environment at a single moment in time. Imagine that pond constantly bombarded by stones of all sizes igniting active energy into the thermal environment at every millionth of a second. Now imagine the two-dimensional surface of the pond in three dimensions. This three dimensional image is our universe with the largest rocks representing the stars and all the other rocks representing every match, every car engine, every campfire, every light bulb, every furnace, etc…

The transfer of vibrations is also influenced by the type of atom energy is passing through. All atoms conduct vibrations, but some atoms are more efficient than others. This depends on whether an atom has weak electrons or strong electrons (8). Atoms with weak electrons pass vibrations faster because during the collision the weak electron is actually passed onto the other atom.

> ", energy is transferred by collisions between free electrons and fixed molecules. A molecule vibrating energetically about a fixed position transfers some of its vibrational energy to a free electron, which in turn passes it on to a less energetic molecule" (9).

Due to the mobility of these free electrons they are capable of transferring vibrations at much faster rates compared to molecules with strong electrons.

Radiation - Electromagnetic Wavelengths

Active energy also occurs as electromagnetic wavelengths. Radiation is the termed used to describe this process.

> "By the action of heat radiation, heat is separated from its association with matter. It is true that heat radiation can pass through some materials such as air or glass, but not as perfectly as through empty space" (10).

It is a process that effectively carries and distributes energy over distance. This radiant energy travels through space until striking an object, which then absorbs the energy from the electromagnetic wavelengths converting it to vibrational energy.

Convection - The Third Process

A third process also occurs as a result from either or both processes of conduction and radiation. It is a process which is created because of a difference of temperature within a single mass of liquid or air.

> "Unlike conduction, which is a transfer of internal energy between fixed atoms or molecules, convection involves an actual movement of mass from one place to another" (11).

> "because of expansion an object at a higher temperature usually has a larger volume than the same object at a lower temperature. So an object at a higher temperature has a lower weight density than the same object at a lower temperature. According to Achimede's principle, the warmer (less dense) fluid will rise, while the cooler (more dense) fluid will sink" (12).

Chapter Conclusion

The thermal environment is energy surging through the universe via vibrating molecules and electromagnetic wavelengths. It is a complex and dynamic relationship that is always in flux. But what do these vibrating molecules and electromagnetic what-evers have to do with walruses and architecture?

Returning to the pond scenario once again imagine a single minute sand particle representing the metabolism of a single walrus. Through the process of metabolic reactions within the walrus potential energy is ignited into kinetic energy. However the ripples from the metabolic reactions are dissipating into the surrounding arctic thermal environment. Because of this the metabolic reaction must continuously ignite kinetic energy in order to maintain the specific temperature required for the survival of the walrus. Now imagine placing a membrane around the walrus. For a walrus this is a thick layer of blubber and skin. The vibrations from the metabolism still ripple outward, but are abruptly stopped by the walrus's blubber. This is a thermal membrane. It decreases the affect of the rippling vibrations dissipating into the thermal environment. Now that the vibrations are retained within the thermal membrane less potential energy is required since the rate of thermal loss is reduced. The more efficient the thermal membrane is at retaining kinetic energy the less consumption of energy required thus less dependence on the search for food. It is this thermal membrane that has allowed the walrus to survive in the arctic thermal environment.

MEMBRANE EVOLUTION: ANIMALS & ARCHITECTURE

Survival of walruses and architecture in the arctic thermal environment requires maintaining a specific internal temperature. This allows the heart, liver, and every other cell and organ of a walrus to perform properly. The same is true for architecture, except where you may find the liver in a walrus you find a secretary sitting at a desk on the fifth floor of a high-rise building.

With the need to sustain this internal temperature two basic strategies have evolved, thermal conservation and thermal production. Through the consumption of energy such as clams for walruses and natural gas for architecture work is produced in the form of burning calories and heating a boiler system, which are both mechanical means that metabolize and burn potential energy transforming it into kinetic energy within the internal thermal environment. Both of these are thermal production strategies. The goal of thermal conservation is to minimize thermal interaction between the internal and external environments by using the thermal membrane.

The difference between walruses and typical modern design is the path of adaptation. While walruses and architecture achieve the same results, both use starkly different strategies. Walruses have evolved highly efficient thermal membranes, which reduce their dependence on replenishing energy for their thermal production systems. Architecture on the other hand has evolved in the opposite direction, installing massive energy consuming furnaces to compensate for inefficient thermal membranes.

Animal Thermal Evolution

Throughout the animal kingdom optimizing thermal performance is achieved through a variety of adaptations. These adaptations are characterized under two animal groups, homeotherms and poikilotherms.

> "The differences between a poikilotherm (temperature conformer) and a homeotherm (temperature regulator) are multiple and fundamental. Birds and mammals evolved from reptiles and differ from present-day reptiles in possession of a thermoregulating center in the brain, in insulation, in peripheral vascular responses to ambient temperature (which are opposite to those of reptiles), and in type of metabolic compensation" (13).

The membrane of Poikilotherms allows for energy transfer. Poikilotherm's internal functions are designed around a wider variance of temperatures, because their membranes allow a high rate of energy transfer. They do have an internal temperature-regulating system, but the maintenance of their internal thermal temperature is dependent on the temperature of the thermal environment.

> "poikilotherms such as insects, fish, and reptiles; whose body temperature usually varies with and nearly to the same extent as the temperature of the environment" (14).

Unlike walruses this group of animals can survive a wider range of fluctuation in their internal temperatures. However the range of external temperature tolerance also restricts this group of animals to a narrower range of thermal environments. Poikilotherm thermal design is not an appropriate example for architecture to learn from, because it cannot afford a wide range of internal thermal variance especially in the arctic.

Walruses and all other arctic mammals are homeotherms. The body temperature of these animals is maintained by an adaptation of their internal metabolisms.

> "Homeothermy is characterized, in the face of a mostly cold and variable environment, by the maintenance of a high body temperature within a narrow range" (15). "Mammals and birds are homeotherms. In most placental mammals, the lifetime mean of internal body temperature is in the range of 36-40 degrees Celcius, while the average temperature of the environment is usually much lower. Thus, a relatively large temperature gradient between the internal body and its environment is maintained throughout life. A second feature of homeothermy is that the internal body temperature of a standard mammal rarely leaves the range of plus or minus 2 degrees Celcius around its lifetime mean, even if the temperature of

> the environment varies to a large extent" (16).

Both homeotherms and poikilotherms have metabolisms that break down energy into forms of nutrients that replenish bodily cells. However, homeotherms have adapted this metabolic mechanical system to also generate kinetic energy internally, which in turns generates a higher temperature. Keep in mind that this increased metabolism did not occur because of living in lower temperature environments.

> "It is clear that several types of adjustments to cold are theoretically possible - The most economical is structural modification in which insulation of the fur and tissues is increased to such an extent that very low ambient temperatures can be tolerated without increased energy expenditure. The most wasteful are metabolic modifications in which extremes of low temperature that limit survival are extended only by increase in metabolic rate" (17).

The adaptation of homeotherms allowed the animal kingdom to expand into environments with temperatures far lower than normal body temperatures. As homeotherms evolved and migrated into thermal environments with ever increasing lower temperatures the mechanical systems of these animals did not evolve to compensate for lower temperatures and greater loss of kinetic energy.

> "Humans and other mammalian species thrive at air temperatures far below the freezing point of water, and normally do not waste fuel on producing extra heat just to keep warm. Insulating the body is the obvious solution, be it by fur in terrestrial animals or by blubber in aquatic mammals. The development of effective insulation was a primary prerequisite to the evolution of homeothermy" (18).

Studies have shown that the normal resting metabolic rate varies little between homeotherms found throughout the spectrum of thermal environments.

> "The distinction between arctic and tropical mammals was not associated with differences in the resting metabolism or in body temperature, but with differences in body insulation. Arctic mammals were found to have greater pelage insulation than tropical mammals" (19).

The adaptation of insulation is a long-term strategy designed for normal temperature ranges of a specific thermal environment. A typical short-term mechanism for dealing with unusual low temperatures is an increase of metabolic rate to cope with short-term thermal situations.

> "It was found that the tropical mammals that were investigated were very sensitive

> metabolically to lowering of ambient temperatures, as shown by an abrupt increase in oxygen consumption with lowering of temperature. In contrast, the arctic mammals did not begin to increase their metabolism until they experienced much lower temperatures and some could virtually remain in a basal state at temperatures down to – 40 degrees Celsius and below” (20).

The majority of arctic homeotherms use air entrapping membranes to varying levels. Air is an efficient insulator when properly incorporated into thermal design. As an individual molecule it conducts heat poorly (good insulator). However, in large numbers and in an unrestrained space air molecules transfer heat efficiently as a group through the process of convection. The adaptation of fur captures the desirable thermal characteristic of air (conductive insulator) between its hairs, while also limiting undesirable thermal characteristic of air (convection) by preventing the mass of captured air from circulating. This adaptive strategy is found in the long fur of arctic mammals such as foxes, musk oxen, siberian tigers, caribou, polar bears, arctic hares, sea lions and sea otters. It is also found in the thick plumage of arctic birds such as ptarmigan and penguins.

Architecture Thermal Evolution

Terms such as adaptation, evolution, and natural selection describe the process of design. Architects are one of the primary decision makers who define the process of natural selection in architecture. However, they are limited to the palette of structural systems and materials available at the time. And so the evolution of architecture is also dependent not only on the inventions themselves, but also the sequence in which the inventions were discovered.

Architecture's evolution has been influenced by a variety of factors, such as the migration of an exoskeleton stone structural system to an endoskeleton steel structural system. However it is the development of glass manufacturing and the invention of the central environmental control system which have had the greatest impact on the architectural thermal design of today.

Over the course of architecture's evolution the limitations of stone construction and material technologies characterized the majority of architecture's unique thermal design. Early stone designs developed around a peripheral structure system, which in-filled a large portion of the exterior wall. Over time this peripheral wall transformed into concentrated structural supports developed first in the form of columns created by the Greeks, then followed by the arches of the Roman era. These structural developments then culminated into the impressive structural design of the flying buttresses during the Gothic era.

Different from the air-entrapping fur used by many homeotherms, the stone membrane of these eras however did provide an efficient thermal barrier. While fur uses the thermal qualities of air by trapping it between its hairs, stones achieve thermal performance due to the high absorption qualities characterized by the high density of its own material make-up.

It is the voids these structural systems were creating in the exterior membrane which began the thermal evolution leading up to present day architecture. These voids were just that, voids. Although pleasant to have the possibility to open the interior to the exterior there was only a few options of material technologies available to effectively fill the voids. One option stood out from the few others. Glass. From this point on architecture has been at the mercy of people's infatuation with the transparent material.

Glass had been invented centuries earlier, but it wasn't until the 1700's when a manufacturing process was developed to produce not only large sheets of glass, but also a large amount of glass. Now the demand for greater voids grew, so these large sheets of glass could be used. This cycle of larger sheets of glass and larger voids continues today. Even though glass posses positive thermal qualities, such as solar heat collectors, it was the negative qualities that were implemented into architectural design.

> "The dominance of glazing in the exterior facades of the 17th Century are not simply the result of a desire for spatial continuity, view and light, but a wish to maximize the glass area, almost at any cost, with external symmetry as the main ordering principle. In thermal terms, the occupants paid an environmental price for this obsession with glass. Francis Bacon

> wrote about the poor winter and summer conditions in houses such as Hardwick, and winter particularly must have been appalling in the New Hall, as it sat on top of its hill, taking the full force of the cold wind. The occupants' answer was usually to decamp from one part of the house to another in accordance with the season" (21).

The next major step in the evolution of architecture was the transformation of the stone exoskeleton into a steel endoskeleton. The era covering the 18th and 19th Centuries was defined by an iron manufacturing process, which first developed it into cast iron then further refined it into steel. The structural strengths of steel allowed the exterior surface of architecture to be completely free of structural constraints. In a sense it meant there was no membrane and thus no voids. The exterior of the architecture was empty. Exterior design was now limited only to the materials available to create it.

With this third evolutionary step of the steel endoskeleton arose the glass membrane architecture. Glass was quickly progressing forward, developing more efficient manufacturing processes and a higher quality glass. These two steps only further fed the infatuation for glass. This fascination for a transparent exterior wall and with little acknowledgement of its thermal qualities lead architecture down an evolutionary branch of glass membranes.

This evolution could not proceed for long. The views and the experience of this architecture was fascinating, but soon the uncomfortable cold and hot nature of this internal environment could not be tolerated. This next step in architecture's evolution introduces the partner glass needed to sustain its position in architecture's membrane. The boiler and air-conditioner. The central environmental control system provided the necessary heat and coolth production needed to make this thermally inefficient architecture livable. However, this stabilization of a comfortable internal environment comes at a major energy price. The price of excessive energy production. But this excessive energy production was and is still affordable today because of its cheap dollar price. The effects of excessive glass and mechanically systems can be clearly seen today in modern architecture.

All of these innovations and their sequence of discovery have forced architecture down its current evolutionary branch. There has been no innovation capable of creating a new branch; a new evolutionary "architecture species" until now. The invention of polystyrene and the list of other air-entrapping insulations (figure 22.1) created in the last forty or so years are capable of creating a new species. A species which reverses its thermal design and in the processes not only redefines a new functional strategy but also a new aesthetic appearance representative of its new functional design.

This is where architecture's similarity to homeotherm design becomes apparent. All these materials use air-entrapment as an insulating strategy just like the fur of the musk ox and other arctic animals. And just like homeotherms this new "architecture species" will consume energy more efficiently because its thermal performance will be dependent more on the thermal membrane than on the furnace and air conditioner.

Type	Material(s)	Method of Installation	R-value[a]	Combustibility	Advantages and Disadvantages
Batt or blanket	Glass wool; rock wool	The batt or blanket is installed between framing members and is held in place either by friction or by a facing stapled to the framing	3.2–3.7 *22–26*	The glass wool or rock wool is incombustible, but paper facings are combustible	Low in cost, fairly high R-value, easy to install
High-density batt	Glass wool	Same as above	4.3 *30*	Same as above	Same as above
Loose fill	Glass wool; rock wool	The fill is blown onto attic floors, and into wall cavities through holes drilled in the siding	2.5–3.5 *17–24*	Noncombustible	Good for retrofit insulation in older buildings. May settle somewhat in walls
Loose fibers with binder	Treated cellulose; glass wool	As the fill material is blown from a nozzle, a light spray of water activates a binder that adheres the insulation in place and prevents settlement	3.1–4.0 *22–27*	Noncombustible	Low in cost, fairly high R-value
Foamed in place	Polyurethane	The foam is mixed from two components and sprayed or injected into place, where it adheres to the surrounding surfaces	5–7 *35–49*	Combustible, gives off toxic gases when burned	High R-value, high cost, good for structures that are hard to insulate by conventional means
Foamed in place	Polyicynene	Two components and sprayed or injected into place, where they react chemically and adhere to the surrounding surfaces	3.6–4.0 *25–27*	Resistant to ignition, combustible, self-extinguishing	Fairly high R-value. Seals against air leakage.
Rigid board	Polystyrene foam	The boards are applied over the wall framing members, either as sheathing on the exterior, or as a layer beneath the interior finish material	4–5 *27–35*	Combustible but self-extinguishing in most formulations	High R-value, can be used in contact with earth, moderate cost
Rigid board	Polyurethane foam, Polyisocyanurate foam	same	5.6 *39*	Combustible, gives off toxic gases when burned	High R-value, high cost
Rigid board	Glass fiber	same	3.5 *24*	Noncombustible	Moderate cost, vapor permeable
Rigid board	Cane fiber	same	2.5 *17*	Combustible	Low cost

(Figure 22.1)

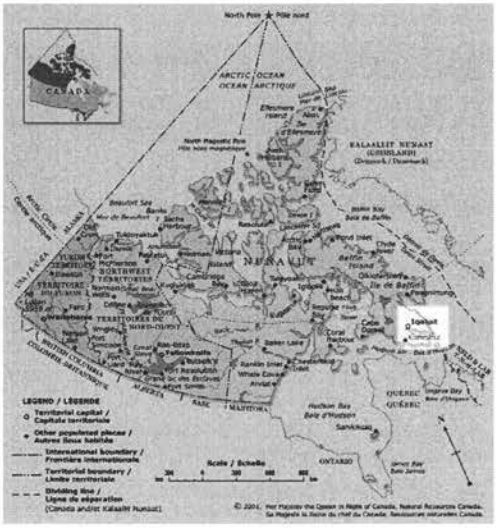
ARCTIC THERMAL DESIGN EXPLORATION

The ability to effectively harness air as an insulator has been mastered by arctic homeotherms not only as a functional element but also as an element of expression. The invention of air-entrapping insulating materials is making a profound impact on architecture functionally, but in design expression they are being sandwiched between bricks and sheetrock. A major reason for this current "sandwich" installation strategy is because of the poor durability characteristics these materials have, which is a necessary requirement for architecture to stand up to the wear and tear of arctic exposure. These materials need a cover, yet not just more bricks. This cover needs to be a partner. A partner that compliments polystyrene, allowing the insulating material to express itself in the architectural design. Teflon fabric.

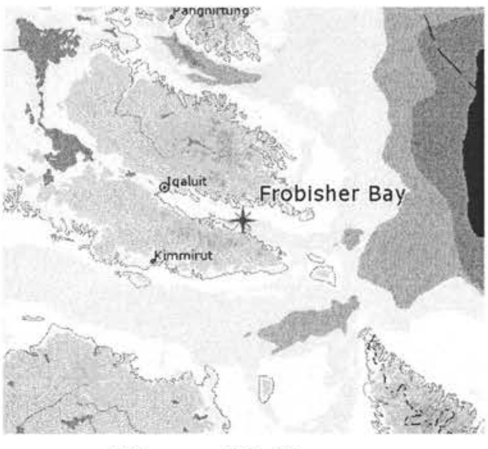
The emphasis of this design project focuses on the expression of this new thermal design material in arctic architecture. This is guided by an understanding of materials and the relationships these materials could develop with the other elements of architecture. However, this exploration will be grounded in an actual design project currently underway in the Arctic. This is a capitol building for the new territory of Nunavut in Canada. The new territory is handling many responsibilities of becoming a new governing body and one of those responsibilities is the design of a capitol building and a capitol district. This design project will use this design scenario as a way of grounding the design process from being more than just a design study of an arctic thermal membrane. This I hope will help to reveal the conflicts which could arise as design focuses on thermal expression as a major design element.

Nunavut Canada

(Figure 25.1)

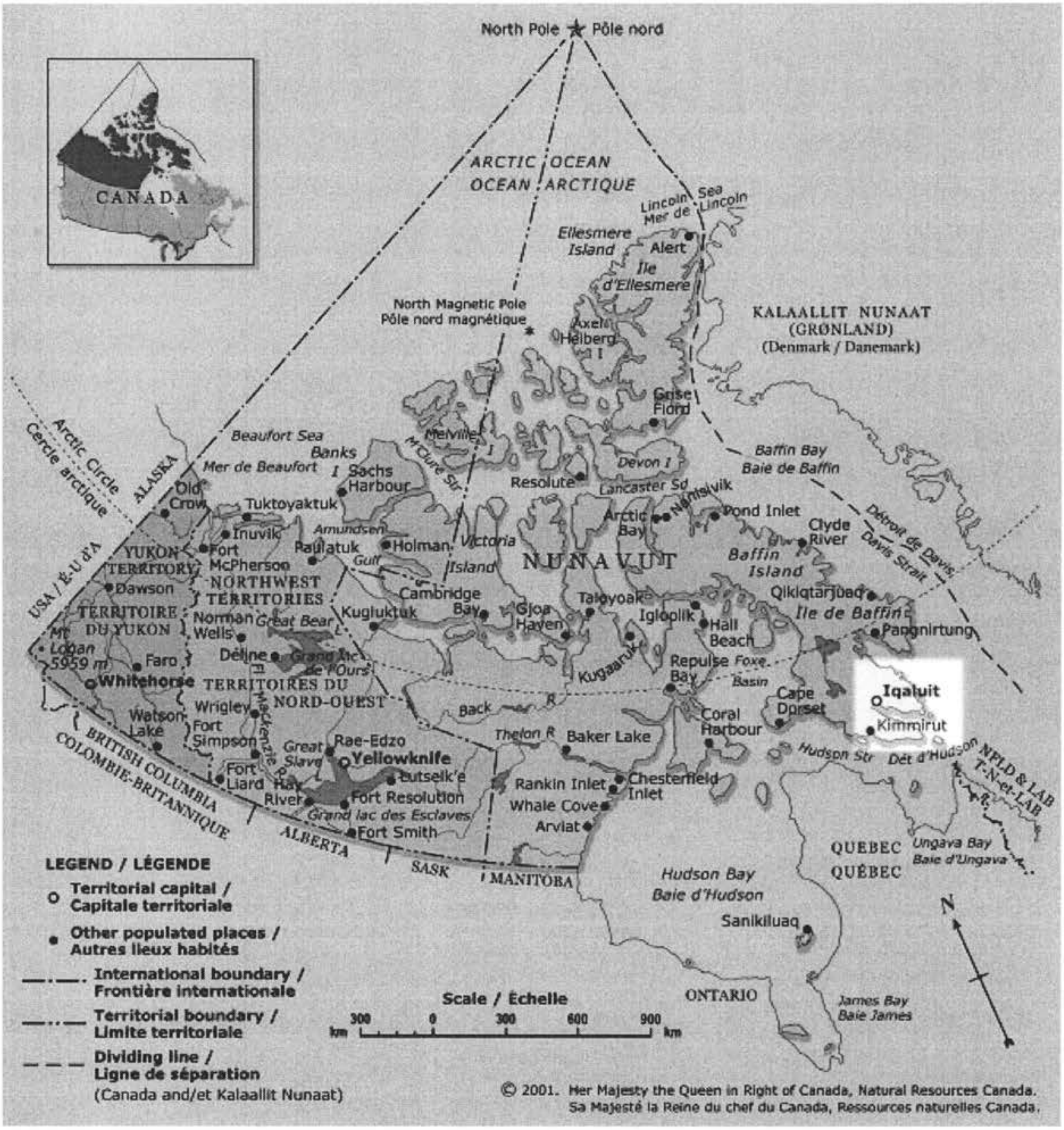


(Figure 25.2)



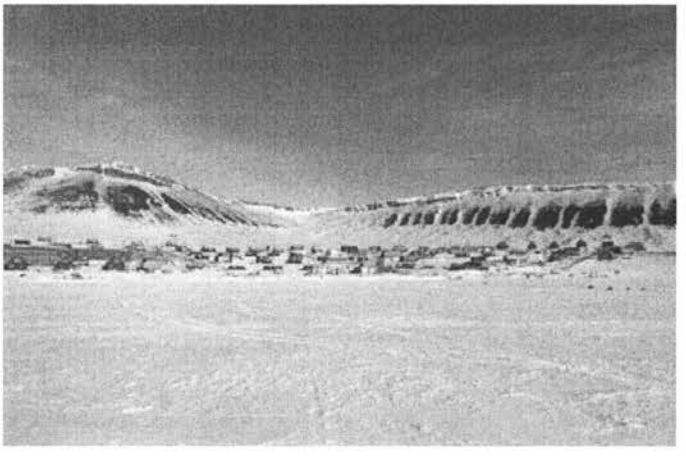
(Figure 25.3)

Nunavut (figure 25.1) is the yellow highlighted territory in the northern portion of Canada. A larger image of Figure 25.2 can be seen on the following page. Located in the small city of Iqaluit (figure 25.2), about two hundred miles south of the Arctic Circle, the site is a proposed theoretical capitol district set on a barren strip of arctic tundra ten miles from the current Iqaluit community. With only nature as the main source of design context, the proposed district for the capitol is nestled into a weather-protected gully along the northwest shore of Frobisher Bay (Figure 25.3).



(Figure 25.2) Enlarged image.

(Figure 27.1)



(Figure 27.2)

(Figure 27.3)

The landscape is rocky with large rolling mountain-like hills surrounding Frobisher Bay (Figures 27.1, 27.2, and 27.3). With this untouched natural landscape as the major site context its seems only logical to embrace the native peoples' emphasis on nature to develop the capitol's design. The thermal exploration of this project only further enhances the connection of design to nature by following the thermal design animals.

This hillside image (Figure 28.1) represents the typical landscape of the Frobisher Bay region, where the capitol building will be located.

(Figure 28.1)

Dome Argument - City of Domes

A logical first step for arctic thermal design would be to minimize the surface to volume ratio through a compact form, thus reducing the amount of external surface. The perfect form either being a dome or a cylinder. The result however requires every building to be a dome. Even though the thermal performance of the dome shape is highly efficient, to consider the aesthetic appeal of not only one building in the shape of a dome, but to consider a city of domes is a tragic architectural loss.

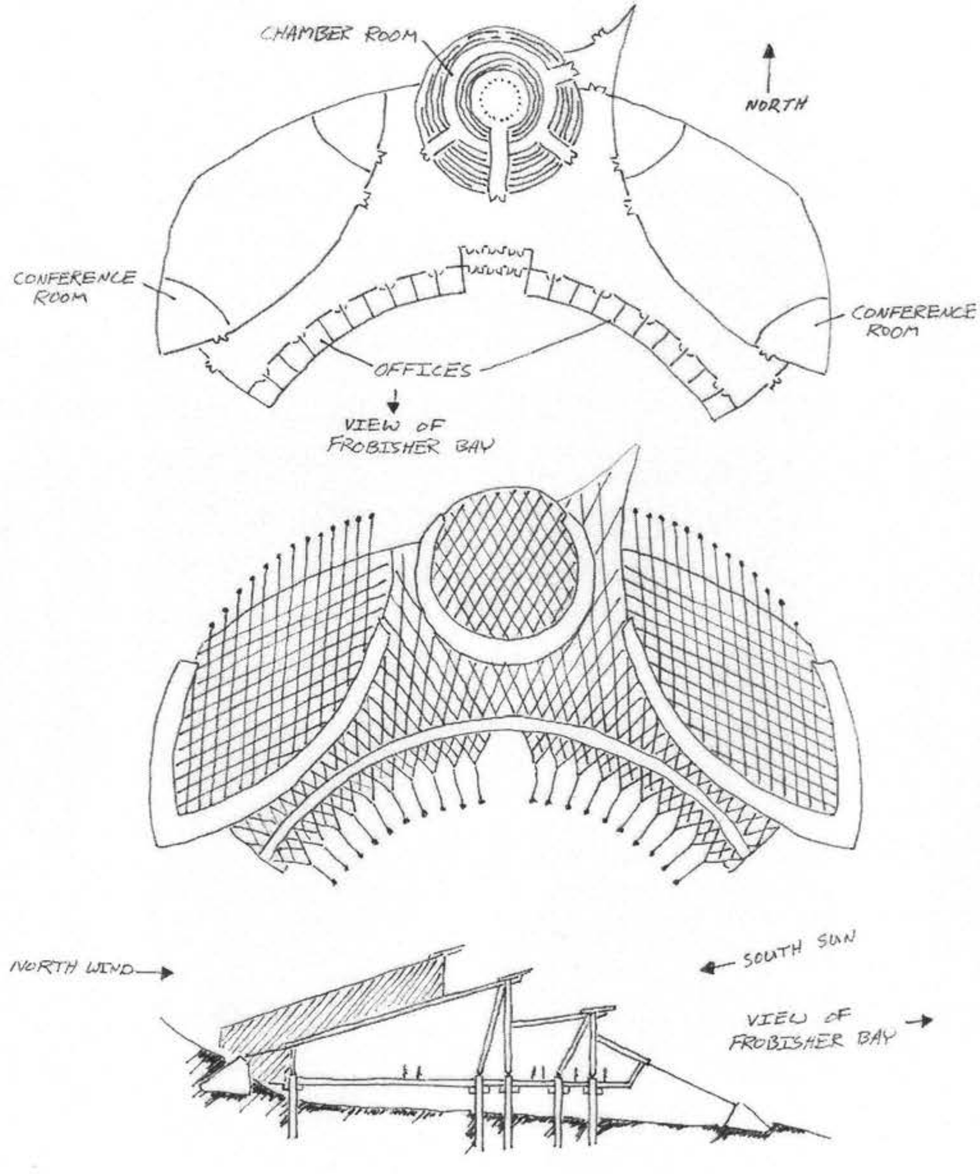
Another issue, which arises from this type of strict massing form, is the conflict this has with building typology. This is especially prominent with a building such as a capitol. Consider a building typology such as a warehouse where the major criteria is one expansive space. Because of this simple program requirement it can easily form into a dome. A warehouse typology does not possess the program elements that demand expression in the massing of the architecture design. A capitol building's program on the other hand is far more prominent than one open space. The powerful elements which comprise the program of a capitol, such as the chamber room where a society's politics are argued and the offices of representatives whom decide the outcome of the arguments, all demand the respect of expression in the architectural design.

Another argument against the dome is found in the animal adaptations this project has been using as a guide for design. As discussed earlier, Homeotherms rely on the membrane as the primary thermal control strategy. If architecture follows this same design strategy, then this allows the massing form of the building to be informed by building typology than by thermal constraints.

However, it must also be understood that this doesn't allow the shape to take any form it wants. Design is about balance, balance that creates the optimal design. Yes, the membrane is the primary thermal control system, however, arctic animals are shaped into slightly more compact forms than animals of the desert. It is just that the differences in form are less significant than the differences in membrane.

Optimal design created through balance is the designer's greatest problem. Even though the shape of the arctic capitol needs to be molded into a compact form, there is no exact measuring system to follow. Yes, some numbers can be calculated to help an architect's judgment, however the final balance of design expression is still based on the personal opinion of the architect.

First Glimpse - Nunavut Capitol Design Sketch



(Figure 31.1)

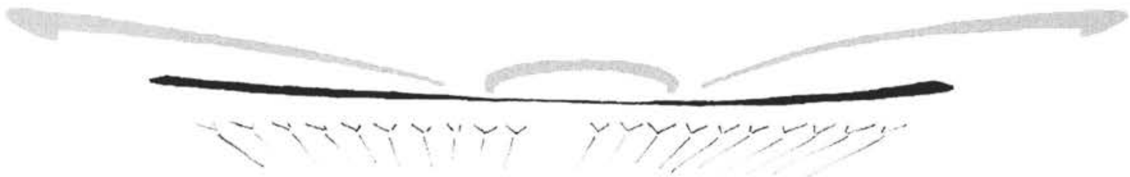
The above sketches (Figure 31.1) illustrate the basic design concept. The middle image presents the roof plan, which is a netting of steel cables attached to wood beams and concrete anchors shown in the bottom sketch of the building section.

Three Form Defining Gestures

Three gestures define the overall architectural massing form of the Nunavut Capitol (Figure 32.1). The first of these three are

(Figure 32.1) Front Elevation Sketch

the nineteen offices for the nineteen representatives of the Nunavut territory (Figure 32.2). Since the government of Nunavut



(Figure 32.2) Front Elevation Sketch

is based on consensus politics- that is, decisions of the legislative assembly will be based on the consensus of the majority of its members, rather than on political party lines- it was important to present the equality of all nineteen representatives in the design. This was accomplished by setting all nineteen offices around the partial circumference of a circle.

The chamber room is the second program element centered above the nineteen representatives' offices then flanked by two elements which appear to reach out and open up to the approaching public (Figure 33.1). It is a circular form to

(Figure 33.1) Front Elevation Sketch

further emphasize the equality of the public and all nineteen representatives. This translates into the interior space by defining the representatives' circular seating located in the middle of the chamber room, which are then surrounded by another circular seating arrangement for the public.

Two main conference rooms then represent the third program element where political agendas are discussed (Figure 33.2). These two spaces are posed under the main peaks of the two wing-like structures that extend outward and upward from the chamber room, providing a dramatic view of Frobisher Bay.

(Figure 33.2) Front Elevation Sketch

Due to the claustrophobic nature of living in the arctic during the long winter months, the spatial quality of these rooms are thrusted dramatically upward to 40 feet above the conference table, providing plenty of spatial comfort.

The Hybrid of Thermal Expression

With the capitol building's overall massing form shaped by its typology the expression of its thermal qualities are then found in the details of its structure and materiality.

The functional aspect of the thermal membrane is straightforward. Choose the most appropriate insulating material and then calculate the thermal transfer rate to determine optimal thickness. However, it is the expression of this architectural element that is less definable.

The relationship between the lightweight thermal membrane and the structural system is a dominant feature in the thermal expression of the capitol building. The structural system enhances the expression of thermal design by complimenting the thermal membrane compared to typical awkward column/beam and cladding system.

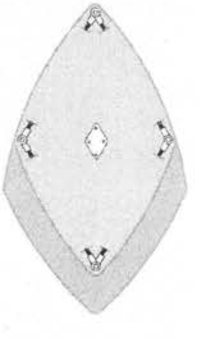
The building system which evolves from this complimenting relationship is a hybrid between the typical column/beam structure and the tensile structure of a tent. This hybrid building system is divided into four major components. The first being the thermal membrane. The second and third are a cable structural system, with the fourth component consisting of wood and concrete columns.

Thermal Membrane

The major difference between homeotherm fur and architecture polyurethane foam is the durability requirement. Fur is temporary and replaceable, while materials like polyurethane foam need to be permanent, but their physical properties lack the durability required for architectural permanence.

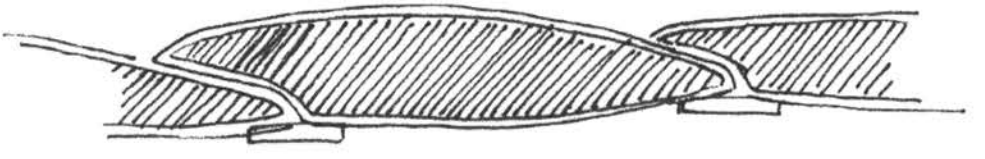
None of these fragile air-entrapping insulating materials are durable enough to stand up to the wear and tear of usage and exposure to natural elements such as the freeze and thaw along with rain, snow, and wind. A protective cover is needed. This is where other material innovations of today are incorporated into the design. High-tech fabrics such as carbon composites and Teflon can provide the durability needed while also complimenting polyurethane foam's thermal expression.

The thermal membrane consists of diamond shaped "thermal cells" (Figure 35.1). Teflon fabric creates the enveloping skin of each cell. This is the durable protective barrier.

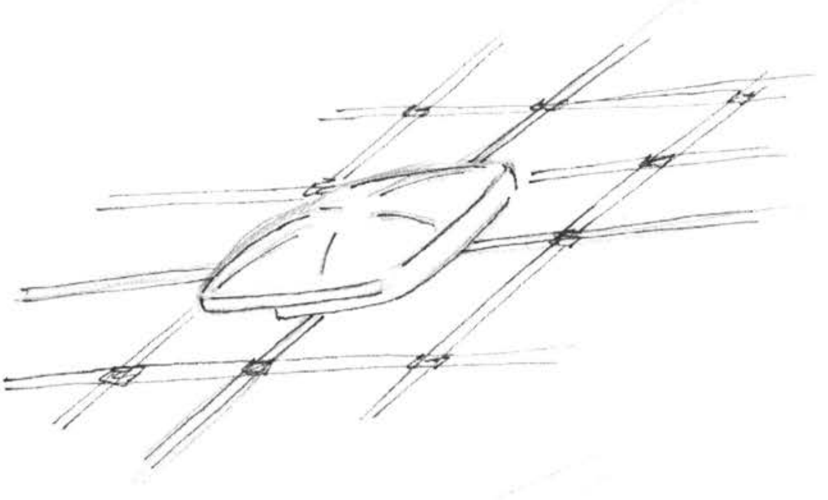


(Figure 35.1) Interior view.

However, unlike bricks and sheetrock Teflon fabric molds and forms to the foam insulation (Figure 36.1), allowing the thermal material to be expressed in the design. The Teflon membrane is left empty until after the cells are attached to the primary cable system. Once, all the cells are attached they are injected with foam (Figure 36.2). They then expand and squeeze up against each creating an air-tight seal. in which foam is then inject inside of it.

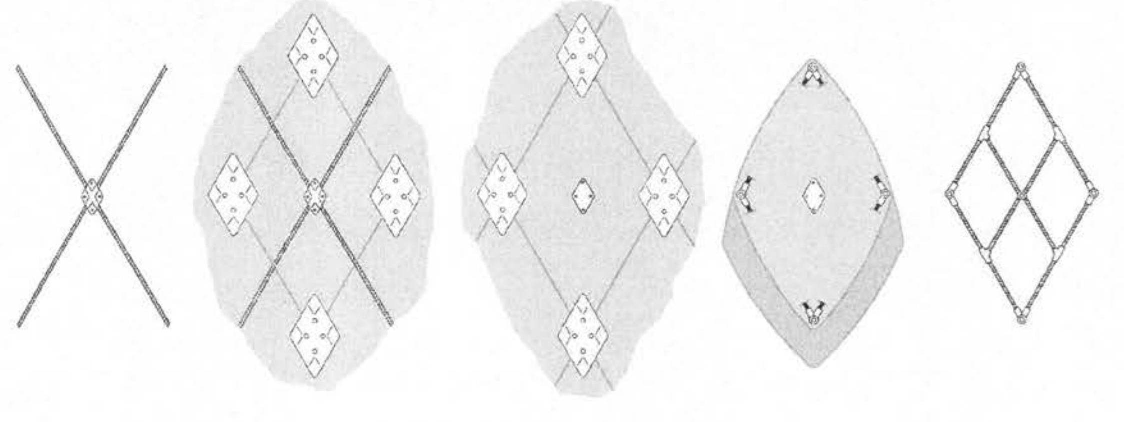


(Figure 36.1) Section through thermal cell.



(Figure 36.2) Thermal cell attached to primary cable system.

The "thermal cell" has a direct relationship with the second component of this building system, which consists of individual cables connected together in the form of the diamond shaped "thermal cell" (Figure 37.5). This diamond cable system is then inserted and interwoven into the Teflon fabric of the "thermal cell" (Figure 37.4). The bottom half of each cell has a flap which extends over the top of the cell directly below it which allows rain to off the building instead of into the building through the seams between each cell (Figure 37.4). All cells are then attached to each other at their corners by diamond shaped steel plates (Figure 37.3). The smaller steel diamond shaped plate in the middle of each cell then connects each cell's internal cable system to the third component of the building system (Figure 37.1) to create the complete membrane system (Figure 37.2).



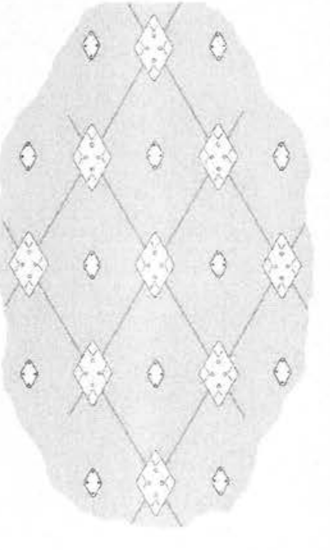
(Figure 37.1) (Figure 37.2) (Figure 37.3) (Figure 37.4) (Figure 37.5)

The above images present the thermal cell from the interior view, showing the cable system as an internal structural system which is protected by the thermal membrane.

The third component consists of the primary cable system which spans the roof and walls (Figure 38.1). This primary cable system is interwoven into a repetitive diamond pattern which allows the cables to criss-cross each other to strengthen the entire system of long-span cables (Figure 38.1). All the individual "thermal cells" first attach to each other (Figure 38.3). Then the cells attach to the primary cables (Figure 38.2).

(Figure 38.1)
Interior view.

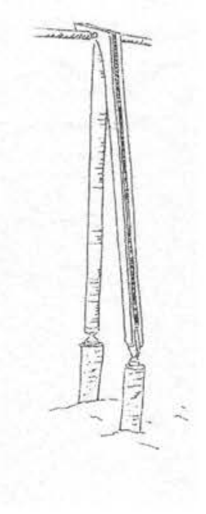
(Figure 38.2)
Interior view.



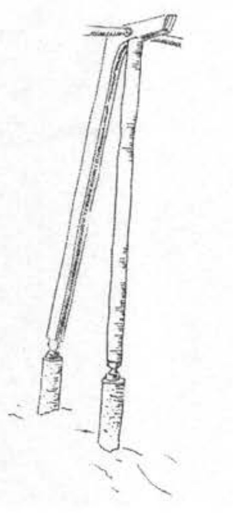
(Figure 38.3)
Interior view.

Thermal Structural System

This membrane of "thermal cells" and steel cables is then supported by the fourth component of this hybrid building system, which is comprised of wood columns perched on top of concrete footings jutting from out of the arctic landscape (Figure 39.1 & 39.2).

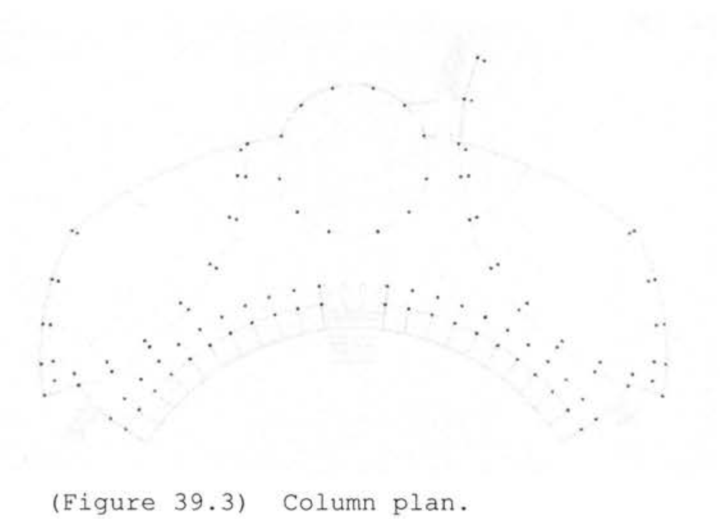


(Figure 39.1)



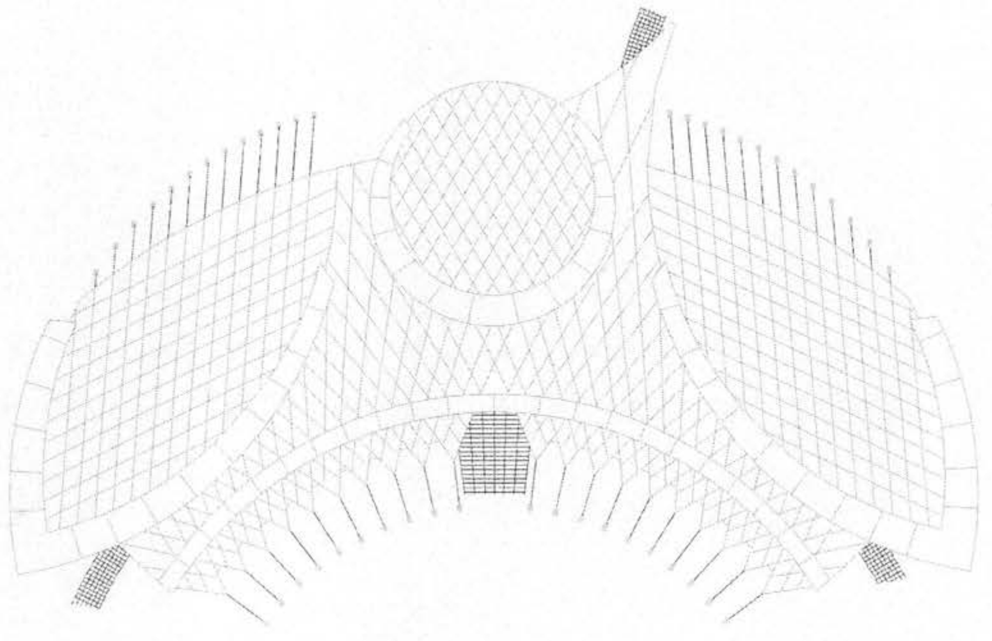
(Figure 39.2)

These columns are placed around the exterior of the three form defining gestures (Figure 39.3).

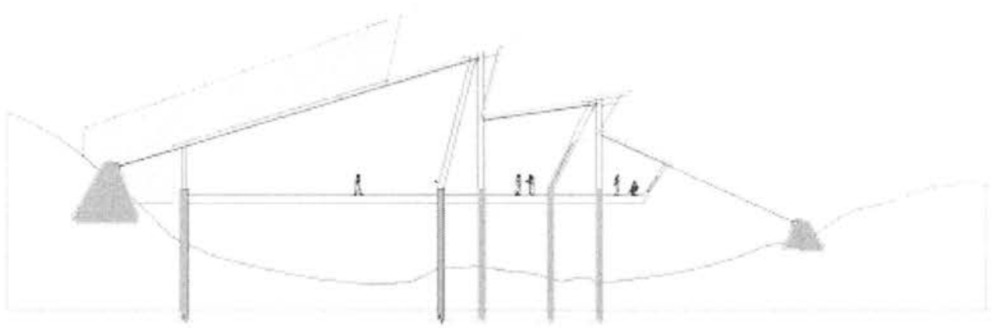


(Figure 39.3) Column plan.

The primary cable system connects the thermal membrane to the wood beams, which are attached to the tops of the wood columns, shown in Figure 39.1. From these wood beams the cables interweave their diamond shaped pattern as they span to concrete anchor supports in the front and back of the building (Figure 40.1 and 40.2).



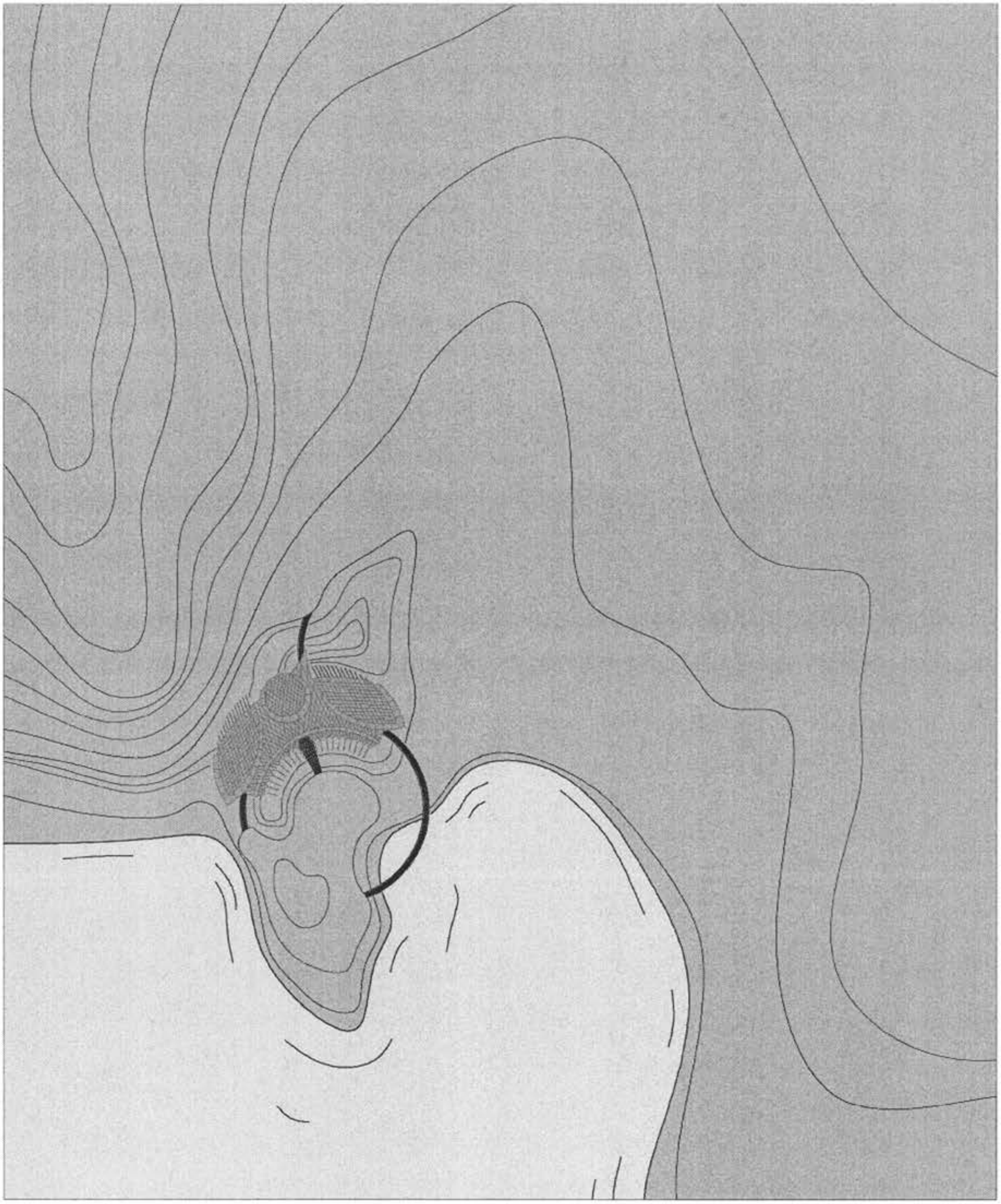
(Figure 40.1) Roof plan.



(Figure 40.2) Section.

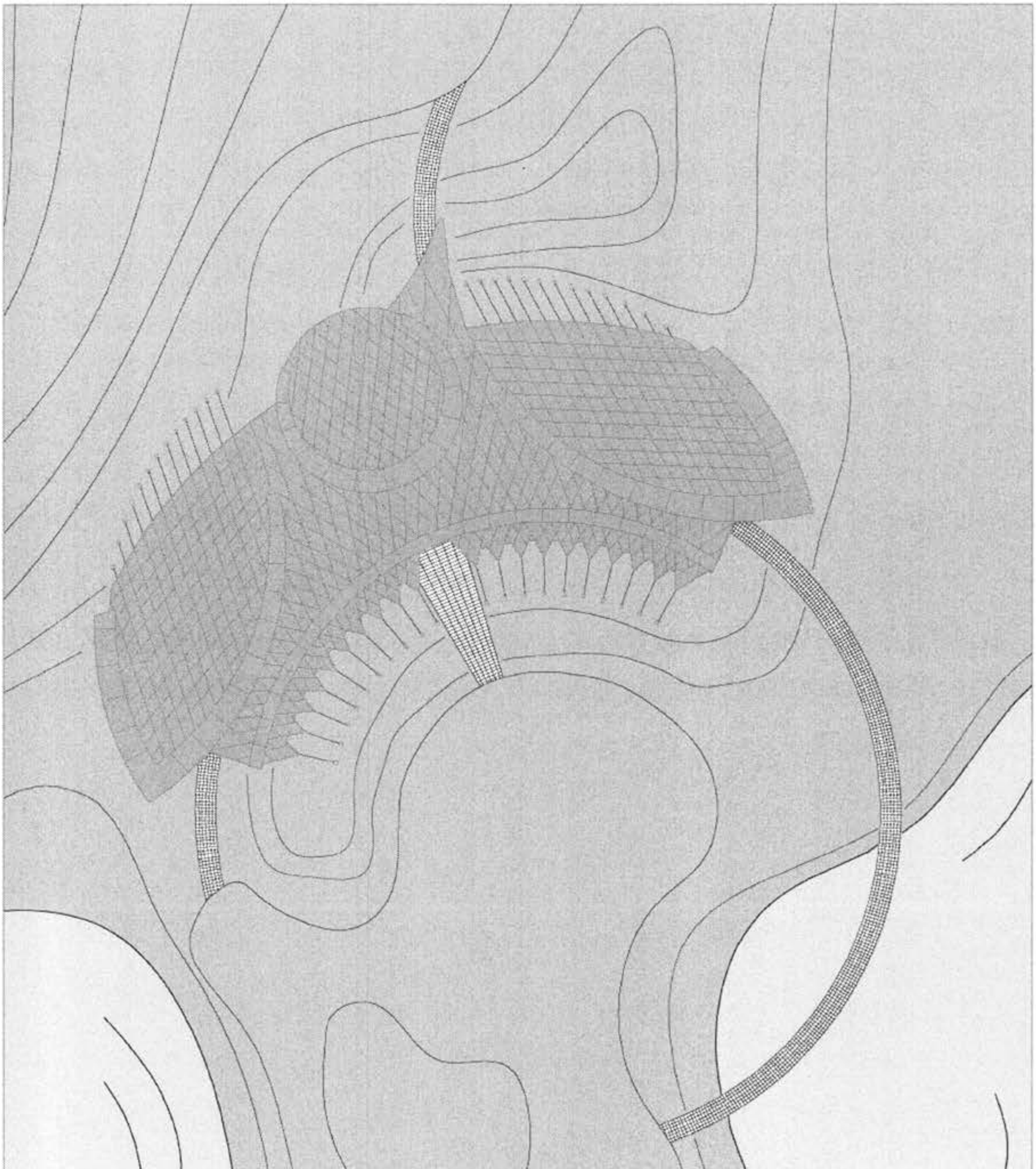
Site Orientation

Even though this building is elevated above the ground it still hunkers against the south side of a hill protecting itself from the most common north winds. Positioned on the main point of land jutting out into Frobisher Bay, the building is then oriented facing south as if opening up to the summer sun, while also providing dramatic views of Frobisher Bay for the nineteen representatives and the two conference rooms jutting out on both sides of the offices (Figures 42.1, 43.1, 44.1, 45.1, and 45.2). The elevated building connects to the landscape not only by the structural concrete columns, but also by the metal bridges which provide the access to the capitol building.

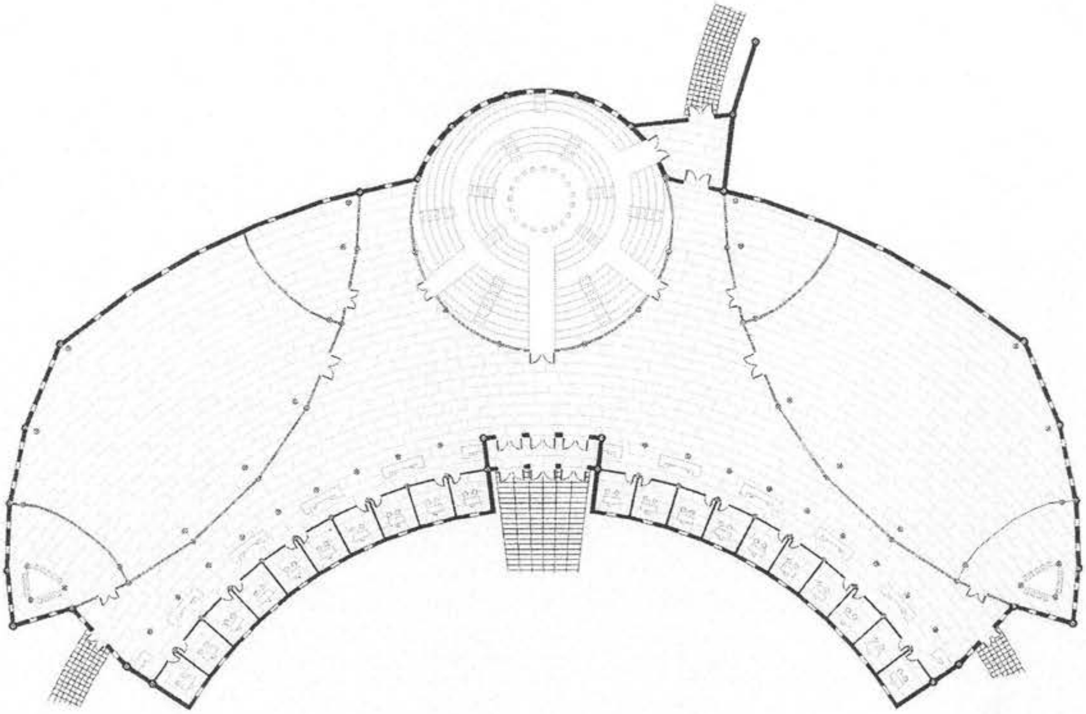


(Figure 42.1) Site plan.

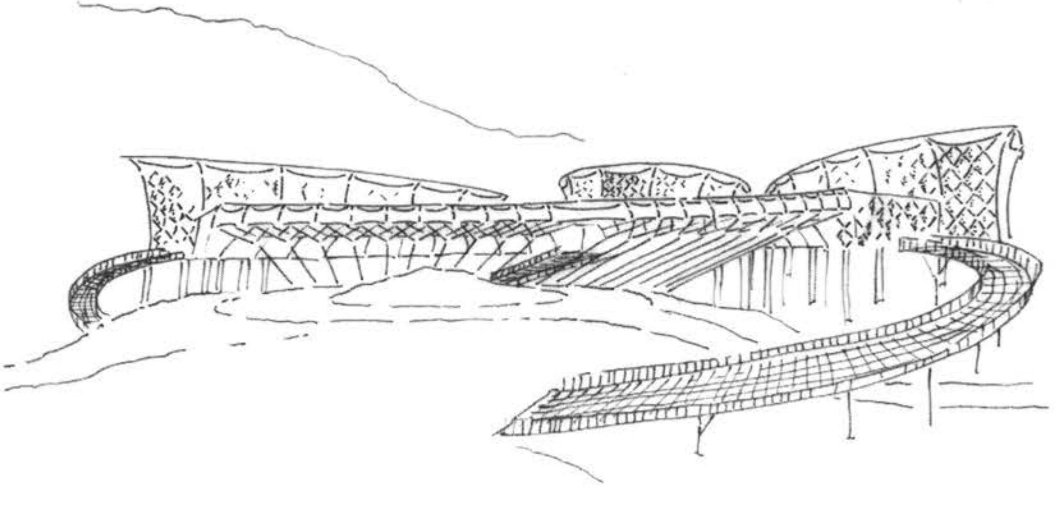
(Figure 43.1) Site plan.



(Figure 44.1) Site plan.



(Figure 45.1) Floor plan.



(Figure 45.2) Front perspective.

Glass - The Unresolved Conflict

Before continuing I want to present a brief argument about another conflict which arose during this design project. High-tech glass windows are available today with high thermal efficiency, in some cases just as efficient as the best air-entrapping insulations. So the window is now an insulator versus a conductor of energy. As stated earlier, historically glass was a major contributor to the poor thermal performance of architecture. While a glass skin building just ten years ago was a hindrance to thermal performance it is now a high quality insulating material (however, only available at a high dollar price, for now). What does this mean to architectural thermal design?

Architecture is not only a visual experience, but also a physical experience. The visual cues should reflect physical properties. A transparent wall provides a visual connection to the exterior from the interior. A solid wall creates a visual barrier between interior and exterior. Just because the window technology exists doesn't mean architecture should be glass buildings. How would it feel to sit next to a glass wall while outside it is minus 60 degrees below zero and a blizzard blasts across the arctic landscape, even if the window is insulating efficiently? In my opinion I feel this would be a visually uncomforting experience, which translates into an uncomfortable experience physically. Thermal expression is about providing the visual cues that relate to our sense of comfort. When considering arctic design a thick puffy insulated wall is much more comforting than a smooth hard surfaced transparent wall.

CONCLUSION

Architecture should not be considered a shield which protects people from nature, but more as the union which connects people and nature. This connection is created through the expression of architecture's functions.

This design project has focused on the expression and function of thermal maintenance, specifically the design of a thermal membrane. Instead of jamming polyurethane foam between bricks and sheetrock, the expression of the thermal membrane provides a connection between nature and people through the union created by architecture. It becomes an architecture that is more than just massive furnaces and air conditioners heating and cooling a space.

This visual bridge establishes another dimension to architecture, however there is more to thermal design than just the **passive thermal membrane**. What happened to the walrus architecture the title implies? A walrus's membrane is not fluffy and furry like an arctic hare or musk ox. Argument accepted - it just makes for a more intriguing title than Musk Ox Architecture. However, there is also much to be learned from the walrus and many other animals. A walrus's membrane is innovative in another way. It uses a thick layer of blubber under a thick layer of skin as insulation. What is innovative about the walrus's membrane is that even though this animal lives in the arctic it still has a problem with over heating from the sun's solar radiation when it lumbers out onto dry land. The walrus cools itself through a process known as shunting. The thick skin of the walrus is full of capillary blood vessels. While in the ocean these capillaries are constricted limiting only a small amount of blood to the skin, thus reducing energy loss. When the walrus begins to overheat while lying in the sun the capillaries expand and fill with blood, which dissipates excess internal energy into the thermal environment, thus cooling the walrus. What would a walrus architecture look like?

Along with the walrus's shunting strategy consider the cooling strategies of an elephant's large ears and a sea lions flippers. Both also have constricting and expanding capillaries. However, the process of cooling is taken another step further, because the ears and flippers are waved back forth to increase energy transfer even more. What would an elephant and sea lion architecture look like?

One of the most sophisticated thermal designs is found in the fur of the polar bear. Its fur consists of transparent hollow haired tubes. These hairs direct the solar radiation like fiber optics onto its black skin, which then absorbs the solar warmth. So while the fur works as an insulator it also performs as a source of energy absorption. Along with functioning as solar collectors the hollow hairs also capture air, which creates an insulating air bubble around the polar bear while it swims in freezing arctic waters. What would a polar bear architecture look like?

Yet another example of thermal design is found on the back of the roadrunner. When cold this desert bird raises its back feathers exposing a patch of black skin. This black skin is directed toward the sun to collect solar radiation thus warming the roadrunner. What would a roadrunner architecture look like?

The list of innovative examples goes on and on. What this presents is how diverse thermal design can be. Architecture can learn from this diversity. However it can also learn from the similarities. While there are many diverse innovations, all are based on similar principles. The emphasis of design is not on reinventing, but instead modifying the existing walrus design.

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